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MATERNAL EDUCATION AND THE GENDER GAP IN EDUCATIONAL PERFORMANCE: EVIDENCE FROM PISA

Master's Thesis
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Abstract of master's thesis

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Abstract

A number of scholars have documented that girls are improving their educational performance relative to boys. This development is seen in the form of increasing female advantage in reading but also as closing of the gender gap in math, that historically is seen to favor boys. Previous literature suggests that the effect is driven by institutions and culture that promote gender equality. In this Master's thesis, I study whether increases in the educational level of women might create a positive spillover to the next generations.

I find that having a college-educated mother is associated with higher performance for their children, girls however benefiting more from their educated mothers than boys. The benefit channeled from mothers to daughters can be observed in all of the studied subjects - math, reading and science – and throughout the score distribution. I also find that girls whose mothers are college graduates, besides outperforming boys in reading also score better than boys in math and science. Meanwhile, father's higher education is not associated with higher female performance. This suggests that mothers are especially influential when it comes to the performance of their daughters.

I find that parents' help with homework and students' own educational aspirations are possible mechanisms behind the gender differentials. My results indicate that girls are slightly more likely to receive help from their parents with the homework relative to boys when either one or both of the parents have a tertiary education. Relative to sons, daughters of educated mothers are also more likely to expect to complete college education.

Keywords gender gaps in education, PISA

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Tiivistelmä

Useissa viimeaikaisissa tutkimuksissa on havaittu, että tytöt parantavat koulumenestystään suhteessa poikiin. Tämä ilmiö on havaittavissa tyttöjen selvästi paremmassa menestyksessä lukutaitoa mittaavissa kokeissa, mutta myös matematiikan osaamisessa. Vaikka poikien on yleensä havaittu menestyvän matematiikassa tyttöjä paremmin, on sukupuolten välinen ero matemaattisessa osaamisessa kaventunut erityisesti maissa, joissa instituutiot ja kulttuuri tukevat sukupuolten välistä tasa-arvoa. Tässä oppinäytetyössä tutkin, onko tasa-arvoon liittyvä naisten korkeampi koulutus yhteydessä seuraavan sukupolven – ja erityisesti tyttöjen – parempaan koulumenestykseen.

Havaitsen, että äidin yliopistotason koulutus on yhteydessä lapsen parempaan menestykseen PISA-kokeessa. Korkeasti koulutettujen äitien tyttäret kuitenkin menestyvät kokeessa poikia paremmin, ja äidin koulutuksen positiivinen yhteys tyttöjen testimenestykseen on havaittavissa kaikissa PISA-kokeen oppiaineissa: matematiikassa, lukutaidossa ja tiedeaineissa. Tämä positiivinen yhteys on lisäksi havaittavissa kaikkialla pistejakaumalla niin heikompien oppilaiden keskuudessa kuin parhaiten menestyvienkin joukossa. Isän yliopistokoulutuksella ei sen sijaan ole selvää yhteyttä tyttärien PISA tuloksiin, mikä viittaa siihen, että äideillä on erityinen vaikutus tyttäriensä menestykseen.

Havaitsen myös, että vanhempien tarjoama apu kotitehtävien tekemisessä ja lapsen omat odotukset tulevasta koulutuksestaan ovat potentiaalisia mekanismeja, joiden kautta vanhempien koulutus vaikuttaa lasten koulumenestykseen. Tulosteni mukaan perheissä, joissa toinen tai molemmat vanhemmat ovat korkeakoulutettuja, tyttäret saavat vanhemmiltaan apua kotitehtävien tekemisessä hieman todennäköisemmin kuin pojat. Korkeakoulutettujen äitien tyttäret kertovat myös poikia todennäköisemmin aikovansa hankkia yliopistotason koulutuksen.

Avainsanat sukupuolierot koulutuksessa, PISA

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1 Introduction

Historically the gender gaps in test scores of math tend to favor boys while girls are often seen to perform better in reading tests (Guiso, Monte, Sapienza & Zingales 2008). Suggested explanations for the emergence of the gender gap are numerous and highly debated. Some of the explanations rely on arguments that the aptitudes to learn certain skills differ by gender. For instance, Baron-Cohen (2003) suggests that men for biological reasons tend to have better spatial abilities while women are seen to perform better in tests than measure verbal skills. There is however no consensus on the literature whether innate gender differences in some skills can cause the widely observed gender gaps in math and reading. Some counter-arguments to the biological explanation state that while males and females tend to have somewhat differing strategies in solving complex mathematical problems, these small differences do not affect ability to learn advanced mathematics (Spelke 2005). Further, it has been argued that while biological differences in aptitudes for specific school subjects may explain differences between genders, the gaps also differ between countries, which cannot be explained by biological factors (Bedard & Cho 2010). This argument entails for considering the cultural or contextual differences between countries that may be involved in the emergence of the gender gaps.

In recent years, scholars have noticed that math gender gaps in PISA test scores decrease or even disappear in countries with higher gender equality, for instance in Nordic countries (Guiso et al. 2008; Nollenberger, Rodriguez-Planas & Sevilla 2016; San Roman & De La Rica 2016). In some of the countries that rank highest in terms of gender equality, girls have even turned the gap in math to their favor. At the same time, in these countries the girls' comparative advantage in reading widens, which indicates that girls improve their overall performance relative to boys in more gender-equal environments (Guiso et al. 2008). While the relationship between gender equality and higher female performance might be attributed to the exposure to institutions that promote equality, Nollenberger et al. (2016) find that within-family transmissions of cultural beliefs also contribute to the closing of the math gender gap. Nevertheless, the findings of these studies suggest that the emergence of the gender gaps is driven by cultural and contextual factors.

The observed changes in gender gaps and the correlation between gender equality and lower gender gaps in math are especially interesting as the gender gaps may translate into differences in occupational choices between men and women and contribute to the persistence of the gender pay gap. OECD (2017a) reports that women are still underrepresented in the tertiary education in fields of science, technology, engineering and mathematics (STEM) accounting for less than 40 % of the new entrants to these study fields across OECD. Furthermore, Paglin and Rufolo (1990) find that mathematical abilities are an important determinant of the study field choice and that individuals with higher math skills tend to choose a STEM career, that are among the highest paying occupations. The authors also find that individuals from the lower end of the math ability distribution - where women are overrepresented - often choose fields such as humanities, education or social sciences where the average income is lower. Thus, encouraging girls to study math and decreasing the gender differences in mathematical ability may contribute to more women choosing a STEM occupation, which in turn might mitigate the gender pay gap. Therefore, the gender gap in math performance not only is an issue of equality in education but also might have an impact on the career choice and income of the individuals.

While the higher female performance associated with better gender equality might be a result of living in an in an environment with institutions and culture that promote gender equality, there may also be other channels through which gender equality improves female performance. One of these channels could be through the impact of education. Bedard and Cho (2010) find that higher share of population with a tertiary education is associated with lower gender gaps in European countries. As higher gender equality is often also associated with higher education levels for women, one could argue that larger share of educated women might especially appeal to girls and thus contribute to the gender gaps. In fact, Baker and Jones (1993) observe a correlation between higher female education and a lower gender gap in math using data from Second International Mathematics Study (SIMS). To shed some light on this possible indirect channel through higher female education, I focus on the education of a woman special for the students - the mother. If higher education level of mothers is associated with higher educational performance for their daughters, increasing educational attainment of women in a society may create a positive spillover to the next generation. Furthermore, this kind of development might also lead to a virtuous cycle of increasing performance for girls.

The objective of this thesis is to study the relationship between mothers' education and their children's educational performance using data from six PISA studies from years 2000-2015. More precisely, I study whether there is a gender differential in the relationship between mother's education and their children's test performance in math, reading and science. In addition, I study two possible mechanisms through which the higher parental education might benefit the children. First, since some previous literature suggests that higher educated parents are more involved in their children's schoolwork (Houtenwille & Conway 2008) and that girls receive more help from their parents with homework than sons (Xu 2005), I study whether the same pattern can be observed in the PISA data and especially whether higher educated mothers are more likely to help their daughters than sons. Second, it has been found that high-educated parents have higher expectations for their children's future education (Carneiro, Meghir

& Parey 2013). One could argue that these expectations may contribute to the child's own expectations of herself and thus also to her motivation. To investigate this possible channel, I study whether maternal education is associated with gender differentials in the student's own educational aspirations.

I find that having a college-educated mother is associated with higher performance for all students but that girls benefit more from their educated mothers than do boys. The magnitude of the benefit channeled from mothers to daughters ranges between 5 to 8% of a standard deviation in all subjects tested - math, reading and science - and can be observed throughout the score distribution. The magnitude of the benefit equals learning gains associated with two to three months of schooling. Meanwhile, father's higher education is not associated with higher female performance, which suggests that mothers are especially influential when it comes to the performance of their daughters. I also find that girls are slightly more likely to receive help from their parents relative to boys in families where either of the parents or both of them have a college degree. Furthermore, relative to sons, daughters of college-educated mothers are 3.3 percentage points more likely to expect that they will complete tertiary education.

This thesis is structured as follows. In the section 2, I present findings from the previous literature related to gender gaps and parental education. In section 3, I describe the data used for the study and in the section 4 I discuss some descriptive findings of the gender gaps in European countries. The section 5 explains the methods of the study and section 6 presents the results. In section 7 I present some extensions to the results and study the heterogeneity of the results in different country groups. In the section 8, I study the possible mechanisms of how maternal education might contribute to higher female performance and in section 9 I present the conclusions from the study.

2 Gender gaps in education

In this section I discuss findings from previous literature that provide background about gender gaps. To gain understanding of the magnitudes and the emergence of the gender gaps, I first present literature that has focused on estimating the size of this gender disparity. Second, I move on to discuss literature that attempts to explain some reasons for the gender gaps especially focusing on the role of culture in the emergence of gender differences in educational performance. In the end of the section, I present findings from literature that studies intergenerational transmissions of education to illustrate the extent to which parental education and their gender role attitudes may impact their children's performance.

2.1 Gender gaps in math and reading

Previous literature from the US finds that the skills in math seem not to differ between boys and girls before the school age. Using data from Early Childhood Longitudinal Study (ECLS-K, a sample of children entering kindergarten), Robinson and Lubienski (2011) and Fryer and Levitt (2010) find no evidence for a math gender gap at the age when children enter the kindergarten. The studies however suggest that boys in the uppermost part of the math score distribution perform better relative to their female counterparts already at the kindergarten start (Robinson & Lubienski 2011; Penner & Paret 2008). Several studies find that a gender gap in math emerges during the first years of schooling. Robinson and Lubienski (2011) observe the gender gap in math emerging as early as by the spring of the first grade. By the third grade the gender gap in math achievement is observed in further studies in varying measures: for the 90th percentile of the distribution (Robinson & Lubienski 2011), throughout the distribution (Penner & Paret 2008) and in the mean (Fryer & Levitt 2010). European evidence from Italy suggest that the gap emerges soon after school start, in the second grade (Contini, Di Tommaso & Mendolia 2017). These findings suggest that instead of the gender gaps reflecting an innate difference, the school system or cultural factors contribute to the emergence of gender disparity in math performance.

When considering the gender gaps in reading, the situation seems to be somewhat different. Fryer and Levitt (2010) find that girls excel in reading already at a very young age and have a 0.15 standard deviation advantage relative to boys when entering kindergarten. Further, the initial female advantage observed in the beginning of the kindergarten persists almost unchanged through the middle school (Fryer & Levitt 2010).

Studies estimating the magnitude of the math gender gap mostly find gaps that range between 0.1 and 0.4 standard deviations. These estimates are of large magnitude as the gains of one additional year of schooling on most national and international test scores correspond to approximately 0.3 to 0.4 standard deviations (Woessman 2016). Estimates of Robinson and Lubienski (2011) suggest that when the children reach the fifth grade, boys outperform girls in math by 0.22-0.30 standard deviations throughout the distribution, while Fryer and Levitt (2010) estimate a 0.2 standard deviation gender gap emerging in the third grade and staying nearly constant from third to the fifth grade. Contini, Di Tommasso and Mendolia (2010) study fifth graders in Italy and using data from the national test INVALSI they observe a math gender gap ranging between 0.13 and 0.25 standard deviations.

Previous literature has shown somewhat less focus on studying the gender gap in reading. Using data from PISA, Guiso et al (2008) estimate that on average the female advantage in reading is almost 0.37 standard deviations within OECD and some partner countries. Pope and Sydnor (2010) find a similar gap of 0.38 standard deviations in favor of girls among eight graders in US. Fryer and Levitt (2010) find a somewhat smaller female advantage of 0.11 standard deviations for fifth graders. Moreover, in reading tests, the gender composition among the high-achieving students appears to be especially disproportionate. Pope and Sydnor (2010) document there being 2.31 girls for every boy among students who perform at the top 5 percent. Together these findings suggest that generally the female advantage in reading is stronger than the commonly observed math disadvantage.

The difference in math scores by gender is found to be the largest among the top performers (San Roman & De La Rica 2016) and the score distribution is seen to shift to be less favorable for girls when the children grow older (Contini et al. 2010). Fryer and Levitt (2010) find that in the fifth grade, the share of females in the top 5 percent has decreased to 38 percent from the 81 percent in the kindergarten. Similarly, Pope and Sydnor (2010) find that among eighth grade students at the top 5 percent of the distribution there are 1.4 boys for every girl. One explanation for the gaps being the highest and the female-male ratios being most disproportionate in the top percentiles is the greater male variability hypothesis. This hypothesis suggests that males are overrepresented in both ends of the performance distribution so that there are more low-achieving and high-achieving students among boys than girls (Hyde & Mertz 2009). Machin and Pekkarinen (2008) find support for this hypothesis in PISA data thus suggesting that greater male variance in test scores leads to a situation where even in the absence of a gender gap at the mean, there are be more boys than girls among the high-achievers. Consequently, the gender gap among the top performers is higher than that at the mean and most detrimental to the high-achieving girls.

When it comes to correlations between the gender gaps in math and reading, the literature is not unanimous whether the gaps move to the same direction or whether better performance for one gender in one subject is associated with a lower performance in another. For instance, Guiso et al. (2008) show that in countries where the gender gap in math is the smallest, girls tend to outperform boys in reading especially strongly. This suggests, that girls close the gap by improving their overall performance, not only by achieving better in math (Guiso et al. 2008). On the other hand, Pope and Sydnor (2010) find that in US states that have the lowest gender disparity in math tests, the gender gap in reading in favor of girls is the lowest, suggesting for better overall equality in the educational performance. Furthermore, when focusing on the observations at the top of the score distribution, San Roman and De La Rica (2016) conclude that among the top performers, while girls do worse than boys in math, they also have a smaller advantage in reading. The authors therefore suggest that the gender inequality is the highest among the high-achieving students.

2.2 Gender gaps and cultural forces

One of the sociological hypotheses trying to explain the emergence of the gender gaps in education is the societal gender stratification theory by Baker and Jones (1993). According to the explanation, in patriarchal cultures where there are less opportunities for female performance, girls do not observe a link between their achievement and their future outcomes. Girls therefore do not strive on domains that they consider less useful for females, for instance math. There are also some psychological theories that support this theory, for instance Eccles' et al. expectancy-value theoretical model suggesting that individuals do not engage in activities unless they expect they will to some extent succeed (Eccles 1994). In the context of educational performance this would imply that if girls perceive that good math skills are not necessary in careers that are suited for women, they might invest less in developing these skills.

There is some relatively recent literature about the relationship of gender equality and the gender gaps in educational performance concluding that gender equality is associated with lower gender gaps in math (Guiso et al 2008; Nollenberger et al 2016; Pope & Sydnor 2010; San Roman & De La Rica 2016). This might indicate that benefits of better math skills become more evident for girls in more gender-equal environments.[1] For instance, Guiso et al. (2008) study the relationship between the gender gaps in educational performance and gender equality using the Gender Gap Index of World Economic Forum as a measure for gender equality. The index determined the level of equality taking into account cultural and institutional factors such as economic and

[1]Interestingly, in a recent study Falk and Hermle (2018) find that higher gender equality and higher economic development are associated with greater gender differences in preferences, such as in altruism, trust, positive and negative reciprocity and patience. If a similar divergence of preferences in educational outcomes would be seen, one could expect that students might have stronger gender-related preferences for school subjects. This might in turn increase the gender gaps. Further, Else-Quest, Hyde & Linn (2010) find that in countries where the gender equity is the highest, the gender differences in motivation to study math as well as self-efficacy and self-concept were the highest and are to the detriment of girls. Also, girls show more math anxiety in countries where the level of gender equality is high.

political opportunities for women, their educational attainment and well-being. Using this approach, the authors conclude that there is a correlation between higher gender equality and lower gender gap in math.

Similar findings have been made in studies that use other measures to imply better position of women in a society. For instance, Pope and Sydnor (2010) study gender gap differences between US states and use survey answers about gender attitudes as a measure for gender equality. They find that in states that rank higher in terms of gender equality, the performance difference between genders decreases, while the states with the most stereotypical gender attitudes seem to focus educational efforts more strongly based on the students' gender. San Roman and De La Rica (2016) in turn study OECD and partner countries and Spain using measures such as political empowerment index for women, female labor force participation and gender housework ratio as measures for gender equality. They conclude similarly that higher levels of gender equality are associated with relatively better math performance for girls.[2]

Nollenberger et al. (2016) question the direction of the causality between the gender gap and the cultural and institutional context. They argue that better female performance in math could also improve female opportunities and outcomes in labor market and thus lead to greater gender equality. To account for this and to disentangle the effect of culture from the effect of institutions, they study a sample of second-generation immigrants. These students who have lived in a host-country since their birth are affected by this country's institutions like their native peers but likely are also exposed to the culture of their parents' home country. Since it is unlikely that these students' educational performance would affect the culture or institutions of their parents' home country, the authors are able to rule out the possible reverse causality. Using this approach, the authors find evidence that higher gender equality measured as the Gender Gap Index in the parents' country of ancestry leads to smaller gender gap in math for their children. Further, the results of this study provide evidence that besides institutions, also cultural beliefs affect the gender gaps in educational performance.

There is some evidence of a decreasing gender gap from the US starting already from the 1970s. The findings of Goldin, Katz & Kuziemko (2006) indicate that boys used to outperform girls in math scores by 0.25 standard deviations in 1972 but by 1992 girls had gained 0.17 standard deviations in performance. While the gender gap in math decreased during the time span, the girls also improved their reading scores relative to boys by the same amount, 0.17 standard deviations. Also Baker and Jones (1993) find that between years 1964 and 1982 the male math advantage in SIMS test decreased in several countries. These findings combined with the more recent studies

[2]Studies only focusing on intra-country comparisons find somewhat less evidence for positive correlation between gender equality and a lower gender gap, but this might be due to possible lower variability in the equality within country than in cross-country comparisons (San Roman & De La Rica 2016; Contini et al 2017)

of the gender gaps turning to favor girls in countries with higher gender equality raise an interesting question of the future trends of the gender differences in educational performance.

2.3 Intergenerational transmissions of education

There exists a large literature about the effects of parental education on that of their childrens, both in terms of length of schooling and the highest completed level of education. It has been argued that mother's education creates positive externalities to the next generation and that the effect of the education acquired by the mother plays a larger role in the child well-being than the education of the father (Doepke & Tertilt 2009; Schultz 2002). Better education for mothers is believed to improve the mothers capabilities to produce human capital for their children, and therefore, promoting better education for women has been considered as a way to improve the educational levels and the well-being of the next generations (Schultz 2002).

Studies of the relationship between the mothers' years of education and that of their children's are however not unanimous. Regardless of the strong correlations between the education of the mother and their children, in many studies the actual causal effect of the education is close to nonexistent or difficult to estimate when ruling out the effect of genetics and other family-fixed effects.

For instance, Black, Devereux and Salvanes (2005) take advantage of an education reform in Norway in 1960s that increased educational attainment in the bottom tail of the distribution and study the effect of parent's years of schooling on the educational attainment of their children. They find a statistically significant and positive causal relationship between mother's education and that of their sons but no causal relationship between mother's education and the education of their daughters. They also observe no statistically significant effect of father's education on their children. The results are however relatively imprecisely estimated and therefore the authors cannot rule out meaningful positive effects either. The 95 % confidence interval of the results implies that the effect of one additional year of mother's education ranges between one less month to two additional months of schooling for their daughters and between one to three more months of schooling for their sons. For fathers' education the 95 % confidence intervals roughly range between one less and two additional months of schooling for both sons and daughters. Thus, the results provide only weak evidence for a causal relation between parents' and their children's education and gender differences in this relationship.

There are also attempts to disentangle the effect of genetics from the effect of education. Behrman and Rosenzweig (2002) study identical twin mothers to rule out differences in inheritable skills and mother's family background to focus on the effect of the education. Plug (2004) in turn studies the correlation between mothers' and their adopted children's education to exclude the effect of inheritable traits. Both studies suggest that the correlations in the educational levels of mothers and their children are mostly driven by inherited abilities rather than a causal effect of the education. These studies also find that the educational level of the father has a significant effect on their children's schooling and that this effect is larger than that of the mother's education. This is contradicting with the common argument that mother's education has a stronger impact for child outcomes. However, the small sample sizes of these studies and their limitations related to the data make it difficult to draw clear conclusions of the findings.

Unlike the previous paper presented, Suhonen and Karhunen (2017) find evidence for intergenerational transmissions of education within family. They study the effect of parental university education on their children's educational performance and attainment taking advantage of new university openings as an instrument variable for parents' university education. Their findings suggest that having a parent with a university degree has a positive effect on the child's years of schooling but that the effect of mother's education is stronger than the effect of father's education. Moreover, they find that having a parent with university degree is associated with higher grade point average for the children. Parents' better access to university leads to a one-grade increase in the child's first language grade and around 0.6 grades better performance in math. The grades are measured as the children leave the comprehensive school at the age of 16. Their estimates also suggest that the benefit in grades is especially related to the mother's better access to university education but they do not study gender differentials in the effects.

All in all, as concluded by Holmlund, Lindahl and Plug (2011) studies aiming to estimate the causal effect of parents' education on that of their children tend to find different results depending on the identification strategy they use and the estimated effects are generally small. However, an interesting and common finding of these studies is that when looking at the effect of the mother's education on the education of their children alone, the estimates catch to a large extent the effect of the father's education (Behrman & Rosenzweig 2002; Plug 2004, Suhonen & Karhunen 2017). This effect arises due to assortative mating between highly educated women and men, which leads to significantly smaller estimates for the effects of the mother's education when controlling for the education of their husbands (Behrman & Rosenzweig 2002).

While the literature of intergenerational transmissions of education is relatively large, there are not as many studies about the relationship between parents education and their children's educational outcomes by gender. The ones that address the topic, Fryer and Levitt (2010) studying students in the US and Contini et al. (2017) in Italy, conclude rather counter-intuitively, that the gender gap in math widens to the detriment of girls when the mother is a university or high school graduate. According to Fryer and Levitt's (2010) findings, girls fall behind boys in the performance even if the mother works in a math-related occupation. These findings seems to contradict with the common assumption that family expectations and mothers as role models would affect female performance positively.

The findings also contradict with the existing literature about the effect of intergenerational transmissions of gender role attitudes as possible determinants of the gender gap in educational performance. San Roman and De La Rica (2016) find evidence for intergenerational transmissions within families, especially suggesting attitudes being transmitted from mothers to their daughters. They conclude that having a mother who is active in the labor market is associated with a higher math performance of their daughters. This is especially the case in countries where female participation is not very common, and it therefore gives a stronger signal of the gender attitudes. This beneficial effect is also seen to be especially strong for the girls who are in the bottom of the math score distribution. Farre and Vella (2013) in turn study the relationship between the mother's attitudes toward women's role in the labor market and that of her children's. They find that mother's labor market participation is strongly correlated with the views of their sons and daughters. In addition, the attitudes of the daughters are also affected by their own education. Thus, mothers seem to be influential in forming their childrens' attitudes which might also apply in terms of educational efforts.

In the literature there seems to be no consensus of the possible relationship between the education level of the parents and their children, nor of the possibly larger effect associated with the mother's education than that of the father's. Thus, in this thesis I aim to contribute to the existing literature by examining the possibly differential effect of mothers education on their children's performance by gender. Such differential effect would alter the gender gaps and may be exacerbated in countries where women acquire more education, either as a result of or as a driver for enhanced gender equality.

3 Data

The data used in this study comes from the OECD Programme for International Student Assessment (PISA). The assessment is designed to measure the skills and knowledge of 15-year-old students in reading, math and science and has a focus on evaluating the students' ability to use these skills in real-life challenges. The PISA assessment is conducted in OECD member countries and other partner countries every three years. The data used for this study covers all the PISA waves, that is, the years 2000, 2003, 2006, 2009, 2012 and 2015. The data used for the study comprises 922.565 observations of individuals from 30 countries.

In addition to the evaluation of the students' skills in math, reading and science, PISA testing includes a set of questionnaires filled by the students, their guardians and the school principals. The questionnaires provide a large amount of information about the students, their family and the school environment. In this study, besides the performance measures, I use information from the student questionnaire about their parents' education and their own educational aspirations as well as information of who in the student's family regularly helps with the homework. In PISA, the education level of parents is reported based on the International Standard Classification of Education (ISCED) framework. In this study, I use the ISCED levels of 5A and 6 as measures for parents' college education as they correspond completion of Bachelor's degree, Master's degree, or an advanced research qualification such as doctorate (Unesco 1997).

I restrict the sample to EU-28 countries, Norway, Iceland and Switzerland[3]. The rationale behind this restriction is the assumption that the differences in cultural and institutional context within EU-countries and the three other European countries are sufficiently small to allow for comparisons of the countries. Furthermore, the findings of Fryer & Levitt (2010) show that inclusion of Middle Eastern countries has a strong effect on the gender gap estimates as in the countries there is, on average, no gender differential in educational performance.

Table 1 presents the summary statistics of the data. Students who have missing data about gender or parents' education are dropped from the sample. The outcome variables are the test scores in math, reading and science as well as who of the parents usually helps the student with homework and the student's expectations to complete a tertiary education. The tests in PISA are designed to have a mean of 500 and standard deviation of 100 (OECD Glossary 2003). In the sample, the average performance scores are somewhat lower: 499, 495 and 502 points for math, reading and science, respectively. The standard deviations of the scores are slightly below 100. In this paper, I refer to the designed mean and standard deviation when interpreting the

[3]After the restriction, the data covers in total 30 countries, as there is no data available for Cyprus. All sample countries and their abbreviations are listed in Appendix Table A.1

difference magnitudes. This allows for direct conversion of PISA points to correspond the same percentage of the standard deviation.

The descriptive statistics show that while girls outperform boys in reading by 37 percent of a standard deviation, on average boys score 11 percent and 2,5 percent of a standard deviation higher in math and science, respectively. Further, Figure 1 shows the distributions of the performance scores in each subject by the student's gender. Girls' scores are somewhat more concentrated to the mean in math and science than the scores of boys. In math, girls also appear to have somewhat higher densities in the below-mean scores than boys. On the other hand, there is a notably higher female density in reading scores that exceed the mean of 500.

The descriptive statistics also indicate that boys are somewhat more likely to have high-educated parents than girls, but the difference is not very large between the genders. Also, there is no substantial difference between the share of educated mothers and educated fathers in the sample. For both genders, on average, mothers help more with the homework than fathers, and the pattern for mother's and father's likelihood to help the student is very similar for boys and girls. The question of the homework help was only included in the student questionnaire of 2015. In the sample, 40 percent of the students who were asked about their aspirations expect that they will complete a college education. Girls however report more often than boys that they expect to acquire a university degree.

To investigate possible differences in the relationships between parental education and the gender gaps in all European countries and Nordic countries, I compare the results from these two country groups. In Nordic countries children have slightly higher average scores in all subjects compared to the full sample and the share of parents with a tertiary education is higher. In Nordic countries, the children report more often that their parents help them with homework while a smaller share of students expect to pursue a university education.

PISA presents the students' ability measures as plausible values instead of actual test scores of individuals. Using plausible values instead of the scores enables obtaining adequate estimates of the population characteristics (Wu 2005). As the 2-hour-test can only contain a limited number of questions of each domain tested, there is measurement error in the ability assessment (OECD 2009a). To overcome this measurement error, PISA assigns each student a probability distribution of the ability, given his or her answers to the questions. The plausible values are five different scores that are randomly drawn from this distribution and they represent alternative ability scores that could have been obtained in the test (OECD 2009a). The plausible values thus correspond the abilities that the student reasonably could have, based on his or her answers in the test (Wu 2005).

OECD suggests for using each of the five plausible values of a student in specifications and then taking an arithmetic mean of these estimates. However, as San Roman and De La Rica (2016) observe from their estimates, the coefficients obtained when using only one of the plausible vales are qualitatively the same than when taking the average of all the five estimates. Also, Wu (2005), states that population parameters can often be credibly estimated based on a single plausible value. In the specifications, I thus use the fifth plausible value to represent the performance score for each student.

The sample design of the PISA study has two phases, which also affects the analysis. In the sample design, the individual schools having 15-year-old students are first randomly sampled within a participating country. On the second phase, students within each of the sampled schools are randomly selected to take the test (OECD 2017b). The sampling design also uses stratification prior to the sampling to allow for better representation of the population[4]. This two-staged sampling design creates a situation where students from the same school cannot be considered as independent observations (OECD 2017b). Rather, it is reasonable to assume that students from the same school might have more similar characteristics than students from different schools or strata. Therefore, I use the balanced repeated replication (BRR) method to correct the standard errors to take into account possible clustering of the observations on school level and based on stratification variables.

PISA studies also include survey weighting to overcome the varying probabilities for each student to be selected to the sample (OECD 2017b). The weights ensure that each student that takes the test represents a correct number of students in the full population. When using the survey weights the observations generalize to represent the total population of 27 million 15-year-old students living in the selected countries. In the specifications, if not otherwise mentioned, I use these student weights to calculate accurate estimates of the full population.

One critical attribute of the PISA study is that the test is non-incentivized. As the students do not have external incentives to do their best in the test (good test performance will not be rewarded in their grades) it can be argued the the students put lower effort in solving the problems and therefore PISA tests do not capture the actual knowledge of the students. Furthermore, previous work by Segal (2012) suggests that non-incentivized tests, besides measuring cognitive abilities, also reflect the test taker's intrinsic motivation and personality traits. This might however be a positive feature as personality traits that are linked with good performance in non-incentivized tests such as conscientiousness are valued in the labor market. Segal (2012) also finds that in a controlled experiment, women were more likely to try their best in a non-incentivized test than men. If this applies to the PISA test, the gender differences in intrinsic motivation may bias the results. Therefore, to investigate whether the non-

[4]Examples of typical stratification variables are regions within a country, urbanization rates and presence of minority groups (OECD 2017b).

incentivized design affects the female-male ratios along the performance distribution, I calculate the gender ratios in an alternative, high-stakes exam, Finnish matriculation examination (Appendix Figure A.1) The figure displays similar gender ratios for the grade distribution as in PISA. Thus, the figure suggests that the gender differences in the test performance are not significantly biased by the lack of incentives.

4 Gender gaps in European countries

This section focuses on the differences in gender gaps between the European countries. As discussed in the Section 2, recent literature of reasons behind the gender gap finds evidence for a relationship between higher gender equality and better female performance. As a descriptive evidence, and to illustrate the gender gap differences, I compute the gender gaps in European countries. This is conducted by calculating the difference between mean female score and the mean male score in math, reading and science.

Figure 2 presents the gender gaps for the sample countries in 2015. The figure displays the countries in ascending order by the gender gap in math. The figure confirms the findings from previous literature - in countries where the gender gap in math is the lowest or favors girls, the female advantage in reading tends to be the highest. The correlation between the average gender gaps in math and reading performance is 0.76. While the science performance has a strong positive correlation with the math performance (0.85), the gender gap in science performance is generally lower than the female disadvantage in math. However, in countries where the math gender gap is low or favors girls, there is a female advantage in science.

Furthermore, the figure illustrates the special situation in Nordic countries. In Finland, Iceland, Norway and Sweden the gender gap in math is to the detriment of boys in contrast to many other European countries. Also, in Malta, Latvia and Slovenia, girls on average perform better in math test than boys. In all of these countries girls also have a higher mean score in science than boys. The figure also illustrates that the magnitude of the female advantage in reading is substantial in comparison to the gender gap in math and it is especially large in Nordic countries, Slovenia, Bulgaria and Malta. For instance, a female-male gender gap of 45 PISA points in Finland equals a difference of 0.45 standard deviations and average learning gains of one and half years of schooling. Figure A.2 in Appendix presents the evolution of the gender gaps for years 2000-2015. The figure shows that the gender gaps in math and reading have remained relatively stable during all PISA waves. There is however a weak declining trend in the female reading advantage and in math disadvantage which suggest for a slow convergence in performance if the similar development continues.

While estimating the gender gaps in the mean provides information of the averages, this method is not necessarily informative of the extremes of the distribution. Since especially in math and science the gender disparities at the top of the performance distribution may translate into less women choosing STEM careers, the gender gap at the highest percentiles may provide the most valuable information from the policy point of view. Figure 3 presents the male-female ratios in math, reading and science estimated for the full country sample in 2015 to depict the gender compositions in different percentiles of the score distribution. The graph shows that there are more girls than boys who score below median in math. The situation is quite similar in science although there are more boys in the lowest, 10th percentile. In addition, girls are underrepresented at the top of the score distribution in math and science: Above the 90th percentile the female-male ratios are 0.69 and 0.73, respectively. On the other hand, in reading the gender composition favors girls among the top performers: there are roughly 1.3 females for every male in the top 90th and above 90th percentile.

5 Methods and empirical strategy

I estimate the association between mother's higher education and the test performance in math, reading and science by gender using standard OLS regression. The equation is the following:

$$Y_i = \beta_0 + \beta_1 F_i + \beta_2 X_i^{mother} + \beta_3 X_i^{father} + \beta_4 F_i X_i^{mother} + \beta_5 F_i X_i^{father} + \gamma F_i D_{ct} + \epsilon_i$$

in which Y_i denotes the outcome variable for individual i - the test score, educational aspirations or help with homework. The dummy X denotes the higher education of the parent and gets the value 1 if the parent has a tertiary degree. The female dummy F gets the value 1 if the student is a female and 0 otherwise. In addition, I include a set of dummies for all combinations of country, year and gender ($F_i D_{ct}$) to capture factors that affect similarly the test scores of individuals of the same gender in country c and year t. I run the regression for all European countries and separately for Nordic countries to detect possible differences between these two country groups.

In some specifications, I also control for additional individual-level and family characteristics. I include controls for student's immigrant status, index of highest occupational status of the parents and index of family wealth constructed based on home possessions reported by the student. While the immigrant status of a student is likely pre-determined and uncorrelated with the parental education, the highest occupational status of the parents and family wealth might be outcomes of the parental education itself. Therefore they are potentially bad controls. I however include these controls to some of the models to investigate the role of these other socioeconomic factors to the students' performance.

The coefficient of interest is the interaction term of mother's education and the female dummy. It captures the possibly differential relationship between mother's education and the performance of their daughters relative to that of their sons. Thus, the coefficient might uncover reasons behind the gender gaps. While the inclusion of father's education and the interaction of the education with a female dummy provides a point of comparison for the coefficient of interest, it also helps to overcome the possible problem of overestimating the mother's influence in the model. As concluded by Behrman and Rosenzweig (2002) and Plug (2004), when estimating the effect of mother's education on that of their children's alone, due to commonness of assortative mating, the coefficient captures the effect of the father's education as well.

Since focusing only on the differences at the mean would possibly omit differences in the relationship between mother's tertiary education and the gender gap along the score distribution, I also estimate a quantile regression of the model. This is to inspect whether the association between mother's education and the test performance differentiates for students at different parts of the ability distribution. As Penner and Paret (2008) point out, in the context of gender gaps it is not plausible to assume that the high-achieving and low-achieving students are exposed to similar processes in their lives and that these processes would affect the students with the same magnitude. Therefore, focusing on different percentiles will provide more information on the associations at the extremes. Focusing on the top of the distribution is especially of interest if we assume that gender differences between the high-achieving students at least to some extent account for differences in the occupational choices of men and women.

The specification for the quantile regressions is similar to the OLS model and includes the same independent and control variables as well as the country-, year- and gender-fixed effects. The regression is estimated separately for each quantile of interest. The quantile regressions are however not estimated with the survey weighting and accounting for stratification in the sampling, which may impact the interpretation of the results.

The empirical strategies of standard OLS regression and quantile regression largely provide descriptive evidence of the relationship between mother's education and educational performance of their children. As there is no exogenous variation in the mother's education level, estimating a causal effect of the education per se is not plausible with the available data. Nevertheless, the model likely captures effects of factors that are linked to the education level. Therefore, the results of the empirical strategy are likely to capture the causal relation of how having a certain type of a mother can affect the educational performance.

There are two required assumptions for this latter interpretation to hold. The first assumption is, that mothers with and without tertiary education do not differ in pre-determined unobserved factors that would affect their sons and daughters differently. Second, when considering fathers, we assume similarly that fathers who have children with high-educated women do not differ from other fathers in pre-determined dimensions that would have differential effects on their sons' and daughters' educational performance. Since parents with different educational background are likely to differ also in some other characteristics, it is noteworthy to understand that these differences do not cause a threat to the validity of the results. The threat only arises if there is a gender differential in how these characteristics of mothers or fathers affect the children. For instance, one could argue that college graduates more likely have high cognitive abilities that their children will inherit. However, if cognitive abilities are as likely to be passed on to daughters and sons, the inherited abilities will not create a gender gap in educational performance and thus not bias the obtained results.

It might be that women who decide to acquire a higher education, have different values than other women and that these values drive both their educational choices and their parenting behavior. For the interpretation of the results it is also important to recall that the association between parental education and the child's educational outcomes might also reflect differences in home environment. Carneiro, Meghir and Parey (2012) find that additional years of mother's schooling alter the family environment and the type of investments into children. For instance, children of higher educated mothers are more likely to being read to, to have musical instruments at their use or to attend special lessons. Carneiro et al. (2012) and Davis-Kean (2005) also find that higher educated mothers are more likely to believe that their children will go to college, and Davis-Kean further finds that these higher expectations are correlated with the child's higher achievement. Therefore, my results likely not only reflect effects that could be obtained by adding to mothers' schooling but also differences in home environment, parental investments and expectations that correlate with parent's educational level.

6 Results

Results of Table 2 show the relationships between parents' education and the performance scores in different subjects in the PISA test. The results indicate that there is a positive association between having a college-educated mother and the performance in PISA test for all students and in all subjects. The benefit of a college-educated mother ranges around 21 percent of a standard deviation within the whole European sample in the baseline specifications (columns 1, 5 and 9). In Nordic countries the association is however much lower[5], around 8 % of a standard deviation (columns 3, 7 and 11). Having a college-educated father is also associated with higher PISA performance of around 30 percent of a standard deviation in whole European sample and 20 percent in Nordic countries. The magnitude of this association is substantial, it is equivalent to almost one full year of schooling. However, it is likely that parents' tertiary education is linked to greater family income and other socioeconomic factors that may affect the children's educational outcomes. It might also be that college-educated parents have higher cognitive abilities that are also inherited by their children. Thus, the coefficients should be considered as descriptive associations that do not imply only benefits related to the education level but also other unobserved factors.

When considering the gender differentials in performance that are associated with parents' education, the interaction coefficients indicate that having a high-educated mother is associated with higher test scores for daughters than sons. The results of the baseline specification indicate that the benefit of having an educated mother ranges between 5 to 8 PISA points and can be observed for the whole European sample as well as in Nordic countries. The female benefits associated with mother's higher education are 5.9 percent of a standard deviation in math, 5.3 percent of a standard deviation in reading and and 7.5 percent of a standard deviation in science. Besides being statistically significant, the coefficients are also economically meaningful and they correspond average learning gains of two to three months of schooling.

In science, the positive relationship between mother's education and the test score for their daughters is slightly higher than in math and reading. Also, the positive relationship in math and science are somewhat higher in Nordic countries than in other European countries, while in reading the association is essentially the same. Furthermore, it appears that there is no clear gender differential in how the father's education is associated with the students' performance. The coefficients for interactions of father's education and the female dummy are small or even slightly negative and

[5]The differences in the relationship magnitudes between all European countries and Nordic countries might be due to the comprehensive school system in Nordic countries that does not include tracking into academic and vocational schools before the age of 16. Thus, the parents may have less influence on their children's education in Nordic countries where the whole age class has the same curriculum.

most of the coefficients lack statistical significance. When comparing the interaction coefficients of parents' education and the female scores, the results therefore suggest that mother's education is more strongly linked to their daughter's performance than that of the father's.

When the individual level controls are included (even-numbered columns) the coefficients for the associations between parents' education and performance as well as the interaction terms with the female dummy decrease significantly. The interaction coefficients for mother's education and female dummy however remain positive and statistically significant in all specifications. In the specifications for the full sample of European countries, the female benefits associated with mother's higher education are 3.2 percent of a standard deviation in math, 2.9 percent of a standard deviation in reading and and 3.3 percent of a standard deviation in science. Interestingly, the interaction term remains statistically significant and positive even in the sample of Nordic countries, where after the inclusion of the controls, the coefficient of mother's education lacks statistical significance. When the controls are included, the interactions of father's education and the female dummy turn negative and statistically significant in the sample of all European countries and for the reading score in Nordic countries. Although one needs to interpret these results with caution as the individual level controls are potentially bad controls, the results suggests for a consistent female benefit that is associated with mother's education.

To shed some light on differences between the European countries, Figure 4 shows the estimated interaction coefficients of mother's education and the female dummy by country. The full table of the regression estimates can be found in Appendix A.2. The figure illustrates that the female advantage associated with mother's tertiary education varies greatly between the European countries. The associations are generally positive and statistically significant in more than half of the countries. The female benefits associated with mother's education are greatest in Luxembourg, Czechia and Norway where the daughters of high educated mothers score as much as 13-23 percent of a standard deviation higher relative to sons in all subjects. In the majority of the countries, the magnitude of the positive relationship ranges between 5 and 13 percent of a standard deviation. The only clear exception to the general pattern is Poland where having a college-educated mother is associated with a female disadvantage of 8 points in math and 9 points in reading performance. In addition, the figure confirms the findings from the results of Table 2 suggesting that the benefits of having an educated mother are not especially an artifact of Nordic countries, but the benefits are observed in many of the European countries.

Tables 3, 4 and 5 present the results from the quantile regressions in math, reading and science. The results indicate that the female benefit associated with a college-educated mother exists in all parts of the score distribution and is present and statistically significant in all subjects studied. Overall, the positive relationship of mother's education and the score points is highest for girls who score at the lower tail of the distribution. The relationship becomes smaller when moving toward the upper part of the distribution.

The point estimates for the bottom 5th percentile range around 15-16 points for different subjects and correspond a gain of 15-16 percent of a standard deviation or six months of schooling. This implies that the associated benefit is especially strong for the low-achieving girls. At the 95th percentile the magnitude of the association between mother's education and female performance is substantially lower than in the bottom of the distribution or at the mean – 4.7 and 4.9 points in math and science, respectively, and 2.5 points in reading. The results also indicate that while the benefits for the low-achievers are of similar magnitude in all subjects, in higher quantiles the mother's education is associated with somewhat lower female benefit in reading than in math and science. Furthermore, the results illuminate that focusing only on the obtained regression results at the mean would lead to underestimating the benefit of having a college-educated mother for the low-achievers and on the other hand overestimating the benefit for the top performers.

The estimated relationships between father's education and female performance do not suggest for an association as consistent. Although father's education is associated with female benefits of 5 to 6 points in the bottom 5th percentile in all subjects, in higher quantiles the the association appears to be negative. Also, not all of the coefficients are statistically significant. Generally in all subjects, the greatest disadvantages associated with father's education are observed by girls who perform at the median or 75th percentile while the negative coefficients are smaller or lack statistical significance in the 25th percentile and for the top-performers.

7 Heterogeneity analysis

In this section, I study the heterogeneity of the relationship between parental education and student performance within the European countries. First, one could argue that the educational systems in the sample countries are not similar and instead of parents' education level the differences in educational systems might explain the gender gaps. It has been found that in countries where the education system includes tracking into vocational and academic systems at a young age, the effect of socio-economic factors on the school performance is pronounced (OECD 2013). Also, Bedard and Cho (2010) find that in countries where the decision of the school track has to be made early, the gender gaps in educational performance are the highest. They also find that the gap emerges already years before the actual tracking takes place. This might be due to the students knowing already at a young age which track they will choose and then focusing their effort to the subjects considered more useful. It is likely that parent's expectations related to the track choice contribute to the student's own expectations and therefore also to the emergence of the gender gap. Furthermore, it might be that college-educated parents are more likely to encourage their children to choose the academic track and encourage them to focus on subjects that are useful in that context. Further, Pekkarinen (2008) finds that a school system that tracks students at a later age increases the probability of girls to choose the academic track. Thus, it might be that girls are encouraged and have higher aspirations to perform better in late tracking systems.

To assess whether the positive relationship of mother's education is reinforced by the educational system, I divide the countries in three groups based on the earliest tracking age following the categorization of Pekkarinen (2008) and run the model separately for each system[6]. The results in Table 6 show that the female benefits associated with maternal education are not especially pronounced for the early tracking countries. Instead, the highest female advantages are observed in countries where the tracking takes place between the age 12 and 15. However, the education level of the father has an especially large positive association with the student's performance in the early tracking countries. This suggests that socio-economic factors from the father's side have a stronger influence under such school systems.

Secondly, while a large share of educated women might channel greater benefits to girls, one could also argue that the impact of mother's education might be especially strong if having a college-educated mother is not very common. San Roman and De La Rica (2016) discuss that having a working mother might send a stronger signal of gender equality and female opportunities in context where female labor force participation is not very high. Similarly, having a college-educated mother might be especially

[6] See Appendix A.3 for the categorization and the tracking ages by country.

beneficial in cultural context where not many women have a higher education. In addition, the same might apply due to selection if, in a context with a lower female education, the women who acquire a tertiary education are the most able ones. To study whether the associations differ by context, I follow a similar approach as San Roman and De La Rica (2016) and divide the sample in two based on the share of 45–64-year-old women having tertiary education. I run the model separately for the countries in which the share is below the sample median and above it to see whether the associations are stronger in countries where female higher education is not as common[7].

The results in Table 7 show that the female benefit associated with mother's college education is not especially strong for the countries in which female higher education is less common. Instead, the daughters of educated mothers perform nearly 8 percent of a standard deviation higher in all PISA subjects in countries where female education level is high. This finding may suggest that girls benefit more in environments where a larger share of females have a higher education because it might make the female opportunities more evident.

[7] In the sample countries, the median share of females aged 45-64 having a tertiary degree in 2017 is 28,05 % (Eurostat 2018). The selected age group roughly corresponds the age group of mothers of 15-year-old students between years 2000 and 2015.

8 Mechanism

In this section I investigate some possible the mechanisms behind the differential association between mothers education and female and male performance. First, I study whether parents' involvement in the children's schoolwork is associated with their educational level and could contribute to the gender gaps. Secondly, I investigate how the parents' education is associated with the child's own educational career aspirations.

Parental involvement is generally associated with higher educational outcomes for children (Hoover-Dempsey et al. 2001). The likelihood to help or the regularity in involvement may however differ based on their education level and the child's gender. Shumow and Miller (2001) find that parents who are high school graduates are more likely to help their children with homework than parents who did not complete high school. Similarly, Houtenwille and Conway (2008) find that parents' education is positively associated with both at-home and at-school parental involvement. Considering gender differences in the help received, some previous studies find that girls report receiving more help with homework from their parents than boys (Xu 2005; Bonesrnning 2010). Houtenwille and Conway (2008) also document that parents devote more time to discuss study-related topics with their daughters than sons. Besides providing direct help to the students, parents' involvement in their children's homework can also be considered as an opportunity to demonstrate that they consider school work important (Epstein & Van Voorhis 2001) and to show support to what their children study (Cooper, Lindsay, Nye & Greathouse 1998). Therefore, parents transfer attitudes and expectations towards schoolwork and specific subjects while being involved. This might be even more important than the direct effect of help on student achievement because student's positive attitude towards school and attributes such as self-regulation and sense of ability - that are enhanced by parental involvement - correlate with performance (Hoover-Dempsey et al. 2001).

To investigate the possible gender-differentials in help received with homework I study who of the student's parents usually helps them with the homework and whether the parent's likelihood to help is associated with the education level. To assess this I use dummy variables obtained from the student questionnaire to indicate whether each parent usually helps the student [8]. The dummy variable gets the value 1 if the parent regularly helps the students and 0 otherwise. Similarly to the previous models, I regress these dummies on the education level of mother and father and the interaction of these with the female dummy controlling for the set of country-, year- and female-fixed effects.

[8]In PISA Student questionnaire the question is "In your family, who helps you regularly with your homework or private study?". The answer options are Mother or female guardian, Father or male guardian, Sister(s)/brother(s), Grandparents, Other relatives, Nobody and Other person. Out of these options the student can select all options that are true.

The results presented in Table 8 indicate that, mothers who have a tertiary education are slightly more likely to help the child with homework than less educated mothers. Similarly, father's tertiary education is positively associated with the likelihood that he helps the student. In both of the specifications, there is also substitution effect in place when the mother is educated, the father is somewhat less likely to help the student with homework and vice versa. The combined findings indicate that while educated mothers in general are 0.9 percentage points more likely help their children, they are 3.8 percentage points more likely to help their daughters than sons. Similarly, college-educated fathers are 11.5 percentage points more likely to help their children than fathers with lower education, and additional 2.4 percentage points more likely to help a daughter. Thus, we can conclude that daughters receive slightly more help from their parents relative to sons in cases where either one or both of the parents have tertiary education.

The results however do not provide explanation why girls would receive more help from their parents. Some possible explanations include that girls might be more prone to ask for help or that they might need more help in their studies. One might also argue that if the parents see that females have more difficulties in labor market, they might want to show support to their daughters already in their studies to increase their preparedness for labor market.

Another channel through which parents' education may plausibly affect the student's performance is through the expectations that they have for their children. These expectations might in turn contribute to the child's own expectations of herself or create extrinsic motivation and therefore affect the performance. To investigate this possible mechanism, I study whether parents' higher education is associated with the student's own educational aspirations[9]. I run a regression of student's expectations to complete tertiary education on the parents' college education and their interaction with a female dummy. The child's educational expectations are measured as a dummy, taking the value 1 when the child expects to complete a Bachelor's or Master's degree or a doctorate and 0 otherwise.

Table 8 shows the results of the regressions. The coefficients indicate that both parents' tertiary education is positively associated with the students' own expectations of their future education. When considering the gender differences in the associations, daughters of college-educated mothers are 3.3 percentage points more likely to report that they expect to complete a university degree than sons. Conversely, father's tertiary education is associated with 4.8 percentage points lower probability for daughters to expect university completion relative to sons.

[9]The question in the student questionnaire asks: "Which of the following do you expect to complete?". The answer options are the ISCED levels from 2 (lower secondary education) to the highest levels of 5A and 6 (college-education and doctoral level education). Out of these educational levels the student can tick as many options as they expect to complete.

9 Conclusion

The objective of this thesis is to investigate the relationship between mother's educational attainment and the educational performance of their children, especially focusing on gender differentials in the association. I find that there is a positive association between mother's higher education and higher female performance in PISA test. Relative to sons, daughters of college-educated mothers perform 5 to 8 percent of a standard deviation better in all subjects tested in PISA - in math, reading and science. Also, the positive association exists in all parts of the score distribution, being highest for the low-performing students and decreasing when moving to the upper part of the performance distribution. Moreover, the association between mother's education and the female score is stronger than that between the father's education and the score. This suggests that college-educated mothers have stronger influence on their daughters' school performance than college-educated fathers.

As there is no exogenous variation in the mother's education level, estimating a causal effect of the education per se is not plausible with the available data. Instead, the results are likely to capture the causal effect of having a certain type of a mother or the effect of the home environment that educated mothers provide for their children.

The findings also suggest that girls are slightly more likely to receive help from their parents with the homework than boys in cases where either one or both of the parents have tertiary education. Relative to sons, daughters of college-educated mothers are also 3.3 percentage points more likely to expect that they will complete a college degree, which might affect their motivation towards studies. These finding might explain part of the mechanisms why higher education of parents especially benefits girls, but the observed associations are relatively moderate. Therefore, further research on the topic of how parental education affects the students would be needed to provide more comprehensive picture of the phenomenon.

If the results of this study reflect a causal relation and college-educated mothers have a positive effect on their daughters' educational performance, the results would imply that there are relevant intergenerational effects of increasing educational level of women. In that case, policies aiming to improve women's education, besides affecting the current generations, would also transmit benefits to the daughters of the women who obtain a higher education. If increasing the mother's education also leads to higher performance of their daughters, this might create a virtuous cycle of increasing female performance in the future.

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Table 1: Descriptive statistics

	1	2	3
	Mean	Sd.Dev.	N
Male:			
Mother college	0.25	0.43	461,832
Father college	0.24	0.43	461,832
Math score	505.19	96.06	461,832
Reading score	476.94	98.80	461,832
Science score	504.05	99.07	434,651
Mother helps	0.55	0.50	34,637
Father helps	0.46	0.50	34,637
Expect tertiary education	0.35	0.48	181,163
Female:			
Mother college	0.23	0.42	460,733
Father college	0.22	0.42	460,733
Math score	494.06	90.18	460,733
Reading score	513.65	90.32	460,733
Science score	501.56	92.37	432,921
Mother helps	0.56	0.50	35,486
Father helps	0.44	0.50	35,486
Expect tertiary education	0.44	0.50	182,100
Nordic countries:			
Mother college	0.32	0.46	125,972
Father college	0.29	0.45	125,972
Math score	510.17	87.95	125,972
Reading score	509.21	94.10	125,972
Science score	508.10	96.98	125,972
Mother helps	0.73	0.45	8,563
Father helps	0.70	0.46	8,460
Expect tertiary education	0.35	0.49	48,622
Total:			
Female	0.50	0.50	922,565
Mother college	0.24	0.43	922,565
Father college	0.23	0.42	922,565
Math score	499.63	93.34	922,565
Reading score	495.28	96.42	922,565
Science score	502.81	95.79	867,572
Mother helps	0.56	0.50	70,123
Father helps	0.45	0.50	70,123
Expect tertiary education	0.40	0.50	363,263

Table 2: Parental Education and Student Scores in Math, Reading and Science

	Math				Reading				Science			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Europe		Nordic		Europe		Nordic		Europe		Nordic	
Mother college	21.23***	6.10***	8.81***	0.12	21.15***	5.24***	8.90***	0.03	21.55***	6.30***	9.17***	-0.91
	(0.41)	(0.53)	(0.49)	(0.55)	(0.53)	(0.48)	(0.47)	(0.64)	(0.46)	(0.49)	(0.57)	(0.64)
Female * mother college	5.88***	3.19***	6.24***	3.88***	5.28***	2.90***	5.20***	3.23***	7.53***	3.31***	8.09***	4.93***
	(0.56)	(0.46)	(0.71)	(0.69)	(0.60)	(0.54)	(0.73)	(0.82)	(0.43)	(0.51)	(0.76)	(0.73)
Father college	31.42***	12.44***	19.48***	7.15***	30.27***	11.26***	19.99***	7.13***	33.41***	12.63***	20.85***	8.11***
	(0.43)	(0.35)	(0.70)	(0.69)	(0.53)	(0.24)	(0.66)	(0.73)	(0.36)	(0.19)	(0.88)	(0.71)
Female * father college	1.339**	-1.78**	-0.54	0.14	0.41	-3.64***	-1.03	-2.10**	-0.48	-1.86**	-0.58	-0.71
	(0.49)	(0.49)	(0.92)	(0.86)	(0.60)	(0.33)	(0.89)	(1.01)	(0.56)	(0.42)	(0.97)	(0.94)
Constant	486.1***	424.0***	512.1***	459.5***	466.5***	395.1***	489.8***	425.8***	448.7***	412.3***	461.4***	450.9***
	(0.69)	(2.22)	(0.84)	(1.66)	(0.73)	(2.82)	(0.94)	(1.46)	(1.64)	(2.72)	(1.43)	(1.84)
Individual level controls	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Observations	922,565	712,504	125,972	91,427	922,565	712,504	125,972	91,427	867,572	712,504	115,41	91,427
R-squared	0.104	0.186	0.050	0.130	0.117	0.198	0.090	0.167	0.100	0.185	0.070	0.154

Notes: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. The individual level controls include an indicator for student's immigrant status, index of highest parental occupation status and family wealth. Country-, year- and female-fixed effects are included. Student's final weights are used in the estimations.

Table 3: Quantile regressions - Math

	(1)	(2)	(3)	(4)	(5)
Percentile	5th	25th	Median	75th	95th
Mother college	8.98***	17.44***	20.10***	19.30***	16.41***
	(0.78)	(0.49)	(0.45)	(0.48)	(0.63)
Female * mother college	14.84***	11.45***	7.54***	6.66***	4.70***
	(1.12)	(0.71)	(0.65)	(0.69)	(0.91)
Father college	14.86***	28.92***	34.97***	35.44***	31.08***
	(0.78)	(0.49)	(0.46)	(0.48)	(0.63)
Female * father college	5.80***	-0.17	-2.27***	-2.64***	-0.25
	(1.12)	(0.71)	(0.65)	(0.69)	(0.91)
Constant	339.8***	430.2***	494.4***	558.1***	643.6***
	(0.36)	(0.23)	(0.21)	(0.22)	(0.29)
Observations	922,565	922,565	922,565	922,565	922,565

Notes: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 4: Quantile regressions - Reading

	(1)	(2)	(3)	(4)	(5)
Percentile	5th	25th	Median	75th	95th
Mother college	9.54***	19.97***	21.63***	20.05***	18.44***
	(0.87)	(0.54)	(0.45)	(0.44)	(0.60)
Female * mother college	16.24***	9.41***	5.74***	4.18***	2.53***
	(1.25)	(0.77)	(0.64)	(0.63)	(0.86)
Father college	15.53***	30.40***	35.46***	34.00***	28.30***
	(0.87)	(0.54)	(0.45)	(0.44)	(0.60)
Female * father college	5.89***	-1.09	-5.51***	-5.72***	-1.99**
	(1.25)	(0.78)	(0.64)	(0.63)	(0.86)
Constant	301.2***	401.8***	469.1***	532.4***	614.0***
	(0.40)	(0.25)	(0.21)	(0.20)	(0.28)
Observations	922,565	922,565	922,565	922,565	922,565

Notes: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 5: Quantile regressions - Science

	(1)	(2)	(3)	(4)	(5)
Percentile	5th	25th	Median	75th	95th
Mother college	7.85***	17.72***	21.19***	20.55***	18.64***
	(0.81)	(0.54)	(0.48)	(0.50)	(0.67)
Female * mother college	16.42***	12.89***	8.08***	6.67***	4.93***
	(1.17)	(0.77)	(0.70)	(0.72)	(0.96)
Father college	13.60***	29.74***	35.69***	34.81***	29.48***
	(0.82)	(0.54)	(0.49)	(0.51)	(0.67)
Female * father college	4.71***	-0.39	-3.69***	-3.46***	0.062
	(1.18)	(0.78)	(0.70)	(0.73)	(0.97)
Constant	333.4***	426.6***	494.0***	559.9***	645.8***
	(0.37)	(0.25)	(0.22)	(0.23)	(0.31)
Observations	867,572	867,572	867,572	867,572	867,572

Notes: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 6: Parental Education and Scores by Tracking System

	Early Tracking			Mid Tracking			Late Tracking		
	(1) Math	(2) Reading	(3) Science	(4) Math	(5) Reading	(6) Science	(7) Math	(8) (9) Reading	Science
Mother college	20.03***	21.05***	17.36***	19.80**	19.86***	20.67***	24.35***	22.92***	25.11***
	(1.20)	(1.17)	(1.10)	(0.34)	(0.20)	(0.48)	(0.41)	(0.54)	(0.62)
Female * mother college	4.86***	1.97	7.59***	7.47**	7.38*	9.84***	4.59***	4.59***	4.82***
	(1.29)	(1.32)	(1.32)	(0.35)	(0.58)	(0.78)	(0.75)	(0.81)	(0.83)
Father college	38.66***	36.64***	44.85***	29.71**	29.25***	31.42***	28.82***	27.93***	29.29***
	(1.50)	(1.51)	(1.10)	(0.56)	(0.26)	(0.57)	(0.64)	(0.68)	(0.73)
Female * father college	5.54***	4.00**	1.30	-2.16	-3.15	-3.49***	3.33***	2.63***	2.33***
	(1.43)	(1.58)	(1.23)	(0.89)	(0.61)	(0.84)	(0.77)	(0.90)	(0.80)
Constant	492.8***	463.1***	466.3***	485.7***	467.7***	485.4***	481.1***	466.7***	448.3***
	(1.30)	(1.56)	(2.22)	(1.44)	(0.93)	(0.92)	(1.65)	(1.51)	(1.05)
Observations	108,661	108,661	101,157	455,448	455,448	429,52	358,456	358,456	336,895
R-squared	0.076	0.106	0.084	0.120	0.125	0.104	0.084	0.103	0.078

Notes: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1 The countries are divided into three groups based on the tracking age in the school system. The tracking ages by country and the categorization is presented in the Appendix A.3.

Table 7: Parental Education and Scores by Female Education Level

	Low female education			High female education		
	(1)	(2)	(3)	(4)	(5)	(6)
	Math	Reading	Science	Math	Reading	Science
Mother college	23.61***	23.79***	22.73***	17.42***	16.95***	19.47***
	(0.55)	(0.64)	(0.77)	(0.43)	(0.47)	(0.38)
Female * mother college	4.80***	3.82***	7.69***	7.71***	7.67***	7.61***
	(0.70)	(0.65)	(0.93)	(0.63)	(0.68)	(0.56)
Father college	33.60***	32.06***	36.75***	28.06***	27.45***	28.52***
	(0.54)	(0.76)	(0.66)	(0.59)	(0.66)	(0.64)
Female * father college	1.13	0.37	-2.03***	1.77***	0.63	1.77**
	(0.66)	(0.72)	(0.69)	(0.63)	(0.74)	(0.70)
Constant	482.6***	462.6***	450.4***	495.2***	477.0***	462.5***
	(1.14)	(1.12)	(1.42)	(0.96)	(0.92)	(1.16)
Observations	435,340	435,340	412,352	487,225	487,225	455,220
R-squared	0.104	0.122	0.107	0.098	0.104	0.082

Notes: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. The low female education sample comprises of countries in which the share of 45-65-year-old women with a tertiary degree is below the median of the total sample, 28.05 %. The high female education sample includes the countries in which more than 28.05 % of the female population has a tertiary education. Country-, year- and female-fixed effects are included. Student's final weights are used in the estimations.

Table 8: Homework Help and Student Expectations

	Mother helps	Father helps	Expect tertiary education
Mother college	0.009***	-0.020***	0.158***
	(0.005)	(0.005)	(0.002)
Female * mother college	0.038***	0.008	0.033***
	(0.010)	(0.008)	(0.003)
Father college	-0.020***	0.115***	0.23***
	(0.006)	(0.005)	(0.003)
Female * father college	-0.014	0.024***	-0.048***
	(0.009)	(0.006)	(0.003)
Constant	0.679***	0.486***	0.140***
	(0.008)	(0.006)	(0.006)
Observations	74,600	71,499	363,263
R-squared	0.058	0.090	0.143

Notes: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1 Country-, year- and female-fixed effects are included. Student's final weights are used in the estimations.

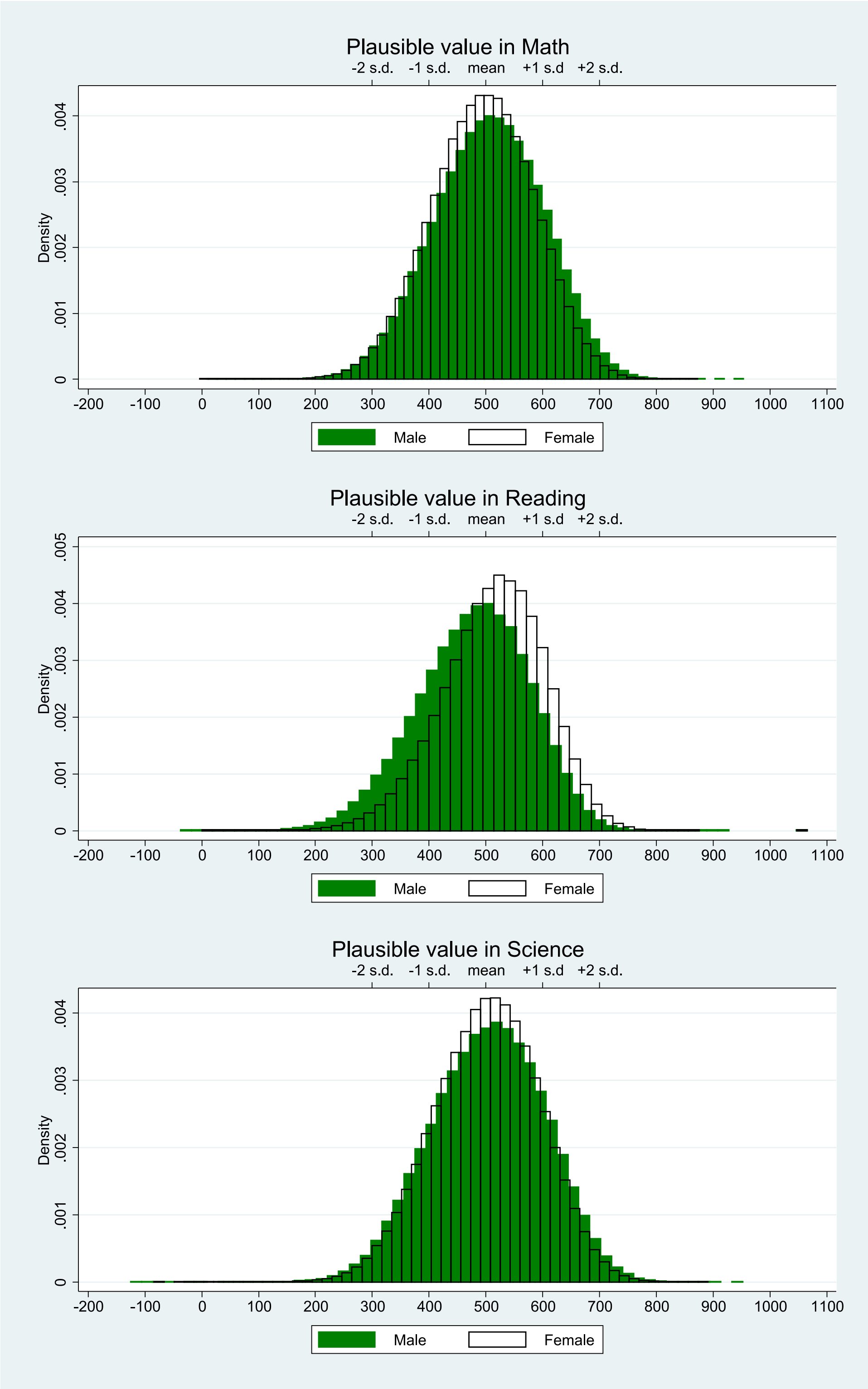

Figure 1: Score distributions by Gender and Subject

Notes: Distributions of female and male scores in math, reading and science. Male score distributions are presented with a solid fill, female score distributions with no fill. The mean and standard deviations represent the values for the whole data set.

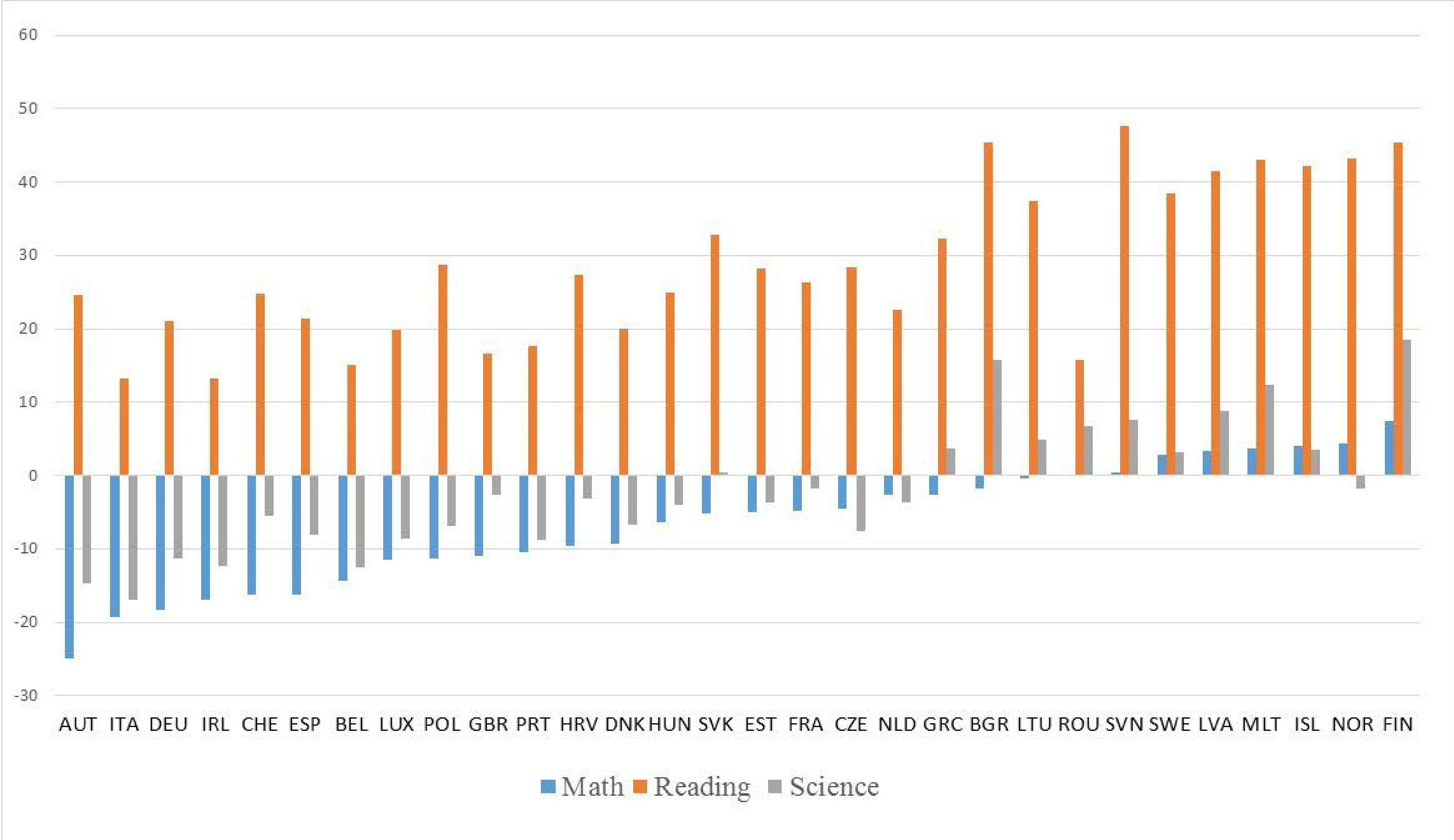

Figure 2: Gender Gaps in European countries 2015

Notes: Female-male differences for mean scores in PISA points in the examination of 2015. Gender gaps are calculated as the difference between the mean score for girls and mean score for boys in the given country. The number of PISA points roughly equals the percentage of standard deviation in each test.

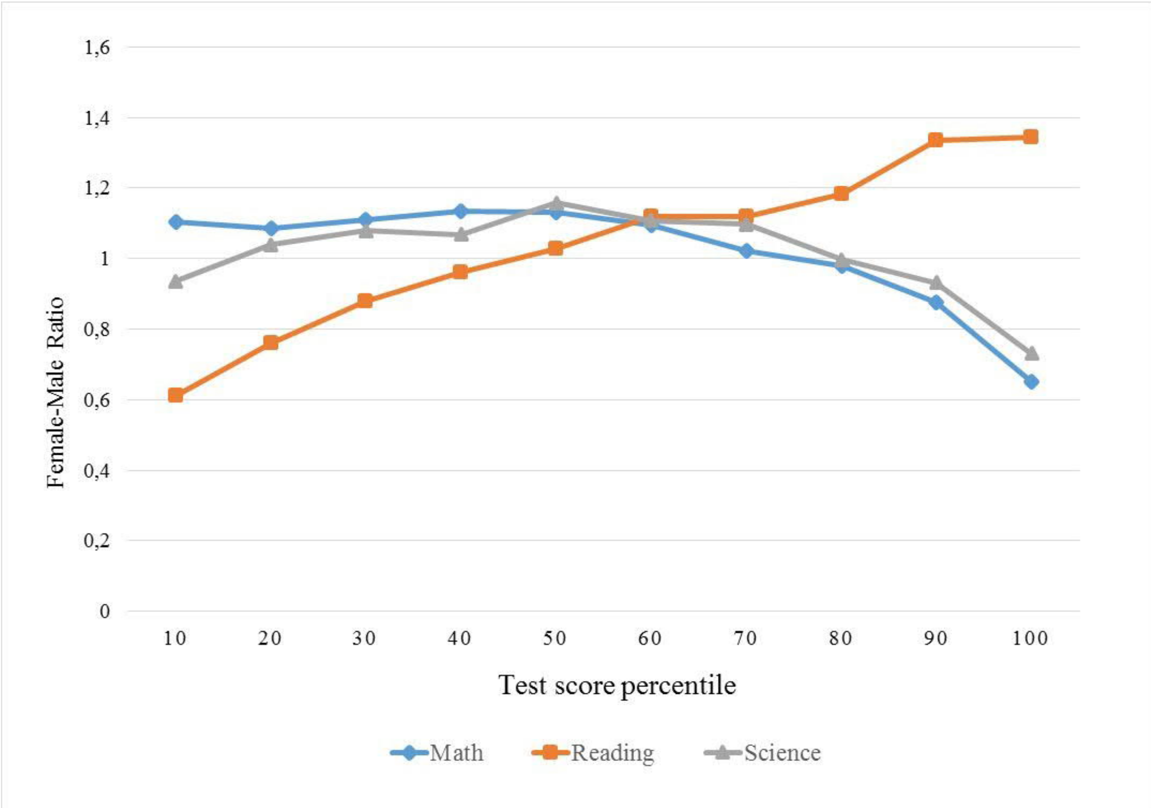

Figure 3: Female-Male Ratios in Math, Reading and Science across Distribution

The female-male ratio on each percentile is calculated by computing the score that is on the percentile of interest, then summing the students' final weights at or below the cutoff score for boys and girls separately and taking the ratio of the two.

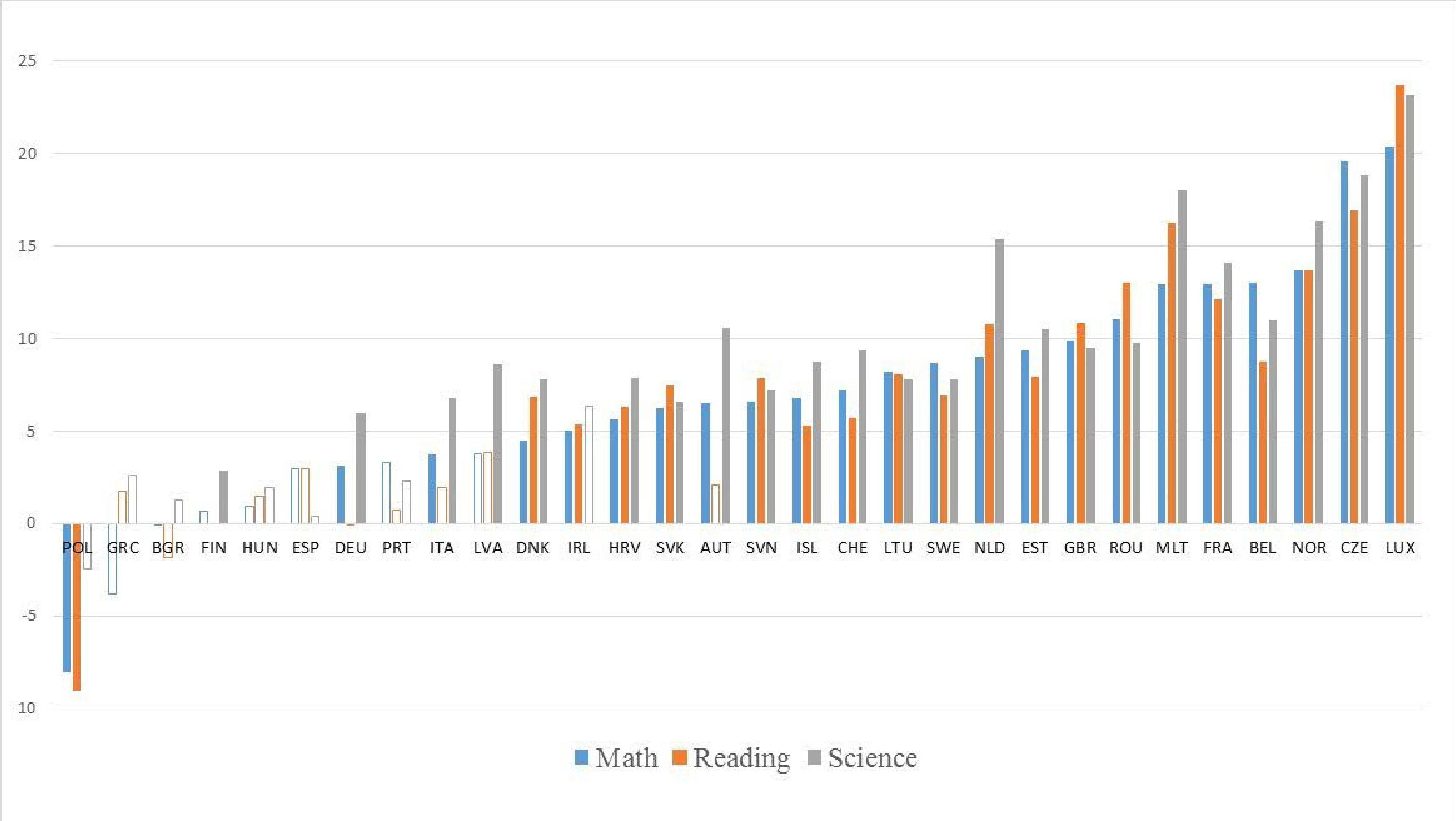

Figure 4: Interaction coefficients for Female * Mother College by Country

Interaction coefficients for Female * mother college by country in the ascending order by the coefficient in math. Coefficients that are statistically significant at least at 10 % level are presented with a solid fill. Coefficients that lack statistical significance are presented with no fill. The specifications are run using the student weights. The full table of the regression coefficients and standard errors is presented in Appendix A.2.

A Appendices

Table A.1: List of sample countries and country codes

AUT	Austria	IRL	Ireland
BEL	Belgium	ISL	Iceland
BGR	Bulgaria	ITA	Italy
CHE	Switzerland	LTU	Lithuania
CZE	Czechia	LUX	Luxembourg
DEU	Germany	LVA	Latvia
DNK	Denmark	MLT	Malta
ESP	Spain	NLD	Netherlands
EST	Estonia	NOR	Norway
FIN	Finland	POL	Poland
FRA	France	PRT	Portugal
GBR	United Kingdom	ROU	Romania
GRC	Greece	SWE	Sweden
HRV	Croatia	SVK	Slovakia
HUN	Hungary	SVN	Slovenia

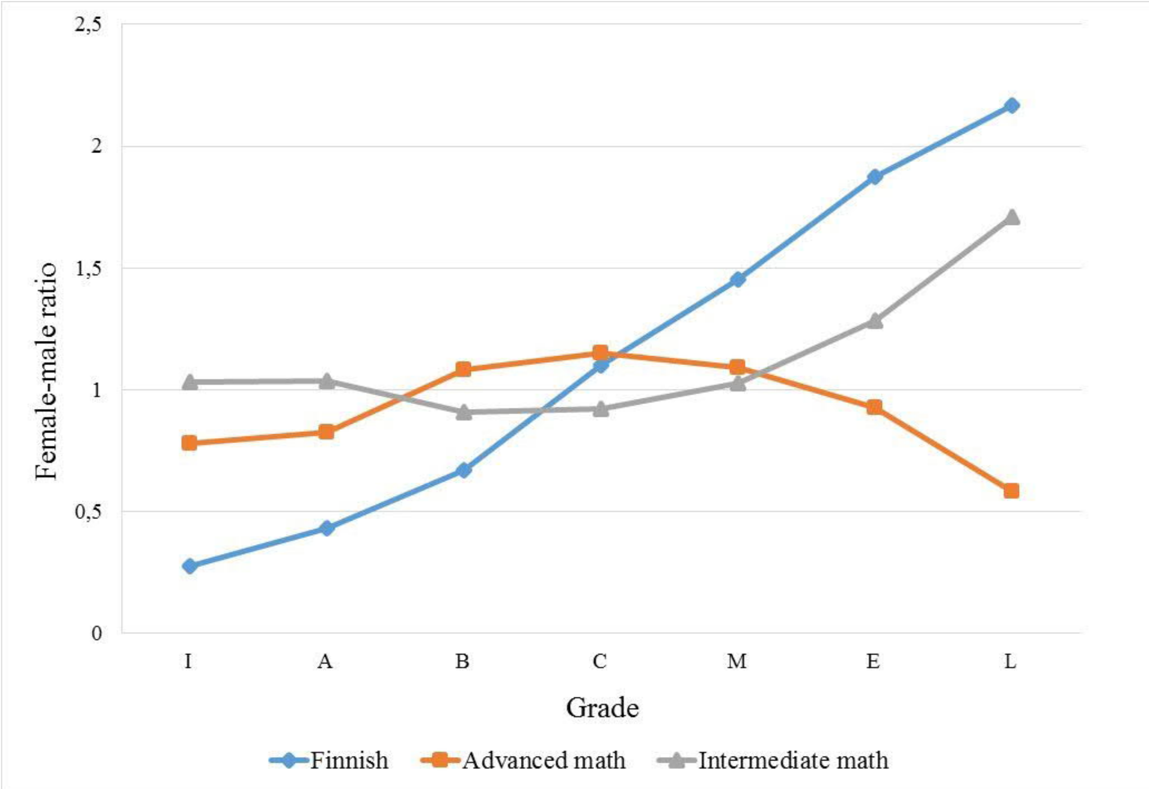

Figure A.1: Female-Male Ratios across Grades in Finnish Matriculation Exam, Spring 2018

Source: Matriculation Examination Board 2018.
Notes: The female-male ratios for each grade in Finnish as mother tongue, advanced math and intermediate math. L is the highest grade and is A the lowest passing grade, I is a fail. The matriculation exam of spring 2018 was especially incentivized as it became more widely possible to apply to tertiary level programs in universities and polytechnics based on the graduation grades without the need to take an entrance examination.

The graph shows a similar pattern as the gender ratios in PISA but a more pronounced one - girls are significantly overrepresented in the upper tail of the grade distribution in Finnish language, that corresponds the PISA score in reading. Further, girls are underrepresented in the top of the distribution in advanced math but more often receive best grades in intermediate math.

Due to there being more women selecting in the upper secondary school and participating in the matriculation exam, the gender ratios are adjusted to reflect a situation in which the initial female-male ratio of the exam participants is 1. The gender ratios are calculated by first taking the female-male ratio of the examination participants and multiplying the number of males receiving each grade by this ratio to adjust for the unbalanced gender composition in the examination. Then the female-male ratio for each grade is calculated by dividing the number of female candidates by the adjusted number of male candidates.

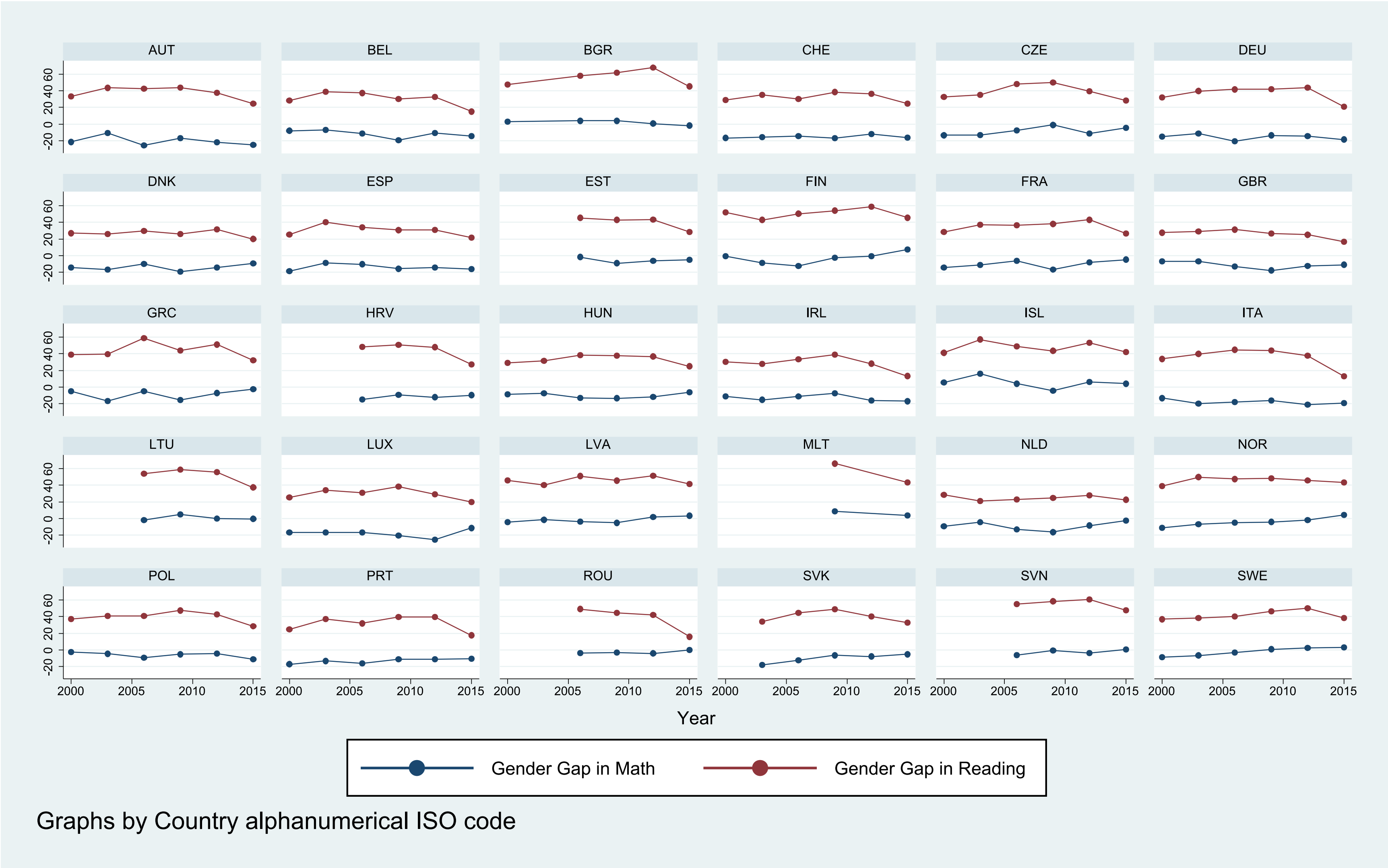

Figure A.2: Gender Gaps 2000-2015

Notes: Female-male differences for mean scores in PISA points in the examinations of 2000-2015. Gender gaps are calculated as the difference between the mean score for girls and mean score for boys in the given country.

Table A.2: Interaction Coefficient Mother College*Female by Country and Subject

	Math	Reading	Science
AUT	6.55***	2.06	10.58***
	(1.91)	(1.75)	(2.34)
BEL	12.99***	8.77***	10.97***
	(1.09)	(1.25)	(1.19)
BGR	-0.09	-1.86	1.31
	(2.28)	(2.09)	(1.74)
CHE	7.20***	5.68***	9.39***
	(1.74)	(1.68)	(1.60)
CZE	19.59***	16.92***	18.84***
	(2.36)	(2.26)	(2.00)
DEU	3.12*	-0.13	5.97***
	(1.55)	(1.99)	(2.04)
DNK	4.47***	6.88***	7.79***
	(1.55)	(1.67)	(1.70)
ESP	2.95*	2.96*	0.39
	(1.66)	(1.48)	(1.59)
EST	9.36***	7.94***	10.48***
	(1.91)	(1.58)	(1.68)
FIN	0.65	-0.02	2.84**
	(1.14)	(1.16)	(1.23)
FRA	12.96***	12.13***	14.12***
	(1.44)	(1.81)	(1.85)
GBR	9.90***	10.82***	9.53***
	(1.58)	(1.97)	(1.61)
GRC	-3.79*	1.74	2.64*
	(2.04)	(2.11)	(1.28)
HRV	5.62**	6.29**	7.87***
	(2.41)	(2.23)	(2.21)
HUN	0.96	1.45	1.94
	(1.49)	(1.36)	(1.79)
IRL	5.04***	5.39**	6.32*
	(1.73)	(2.12)	(2.03)
ISL	6.81***	5.31***	8.77***
	(1.20)	(1.31)	(1.40)
ITA	3.76**	1.98	6.79***

Table A.2: Interaction Coefficient Mother College*Female by Country and Subject

	Math	Reading	Science
	(1.67)	(1.69)	(1.29)
LTU	8.22***	8.08***	7.78***
	(1.31)	(1.49)	(1.19)
LUX	20.40***	23.72***	23.15***
	(1.96)	(2.07)	(1.84)
LVA	3.80*	3.83*	8.63***
	(2.03)	(1.91)	(1.70)
MLT	12.93***	16.27***	18.01***
	(3.46)	(4.72)	(3.78)
NLD	9.01***	10.77***	15.37***
	(1.54)	(1.71)	(1.65)
NOR	13.66***	13.71***	16.36***
	(2.05)	(2.21)	(1.82)
POL	-8.00***	-9.03***	-2.46
	(2.22)	(2.14)	(1.93)
PRT	3.34	0.72	2.26
	(2.42)	(2.37)	(2.00)
ROU	11.02***	13.03***	9.75***
	(2.84)	(2.99)	(2.40)
SVK	6.27***	7.48***	6.61***
	(1.95)	(2.01)	(1.97)
SVN	6.60***	7.87***	7.22***
	(2.01)	(1.63)	(1.67)
SWE	8.71***	6.91***	7.80***
	(1.25)	(1.29)	(1.67)

Notes: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Country-, year- and female-fixed effects are included. Student's final weights are used in the estimations.

Table A.3: Countries by Tracking Age

Early tracking:	AUT	10
	DEU	10
	CZE	11
	SVK	11
Middle tracking:	BEL	12
	CHE	12
	NLD	12
	BGR	13
	LUX	13
	HRV	14
	HUN	14
	ITA	14
	ROU	14
	SVN	14
	FRA	15
	GRC	15
	IRL	15
	PRT	15
Late tracking:	DNK	16
	ESP	16
	EST	16
	FIN	16
	GBR	16
	ISL	16
	LTU	16
	LVA	16
	MLT	16
	NOR	16
	POL	16
	SWE	16